Population dynamics of *Vimba vimba persa* in Iranian waters of the Caspian Sea

by

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ABSTRACT. - The population dynamic parameters of *Vimba vimba persa* (Pallas, 1811) were investigated from 994 specimens collected in the Iranian waters of the Caspian Sea from October 2008 to September 2009. Fork length ranged from 9.5 to 23.4 cm. Von Bertalanffy growth parameters from size-at-age data are: $L\infty = 26.1$ cm, $K = 0.28$ yr^{-1}, to = -0.65. The length-weight relationship coefficient b for males (b = 3.128) was higher than that for females (b = 2.971). The oldest fish was 5 years old. Sex ratio was 1:1.35 (n = 935) with females predominating. Using the catch curve method, the instantaneous coefficient of total mortality Z was estimated as 1.07 yr^{-1}. The instantaneous coefficient of natural and fishing mortality M and F were 0.58 and 0.49 yr^{-1}, respectively. The current exploitation ratio E = 0.46 indicated that the population seems to be highly exploited, and probably not at a sustainable level.

RÉSUMÉ. - Dynamique des populations de *Vimba vimba persa* dans les eaux iraniennes de la mer Caspienne.

Les paramètres de dynamique des populations de *Vimba Vimba persa* (Pallas, 1811) ont été obtenus à partir de 994 échantillons prélevés dans les eaux iraniennes de la mer Caspienne d'octobre 2008 à septembre 2009. La longueur à la fourche était comprise entre 9,5 et 23,4 cm. Les valeurs des paramètres de l'équation de croissance de von Bertalanffy en fonction de l'âge sont les suivantes : $L_\infty = 26{,}1$ cm, $K = 0{,}28$ année^{-1}, $t_o = -0{,}65$. La valeur b pour les mâles (b = 3,128) est plus élevée que celle des femelles (b = 2,971). Le plus vieux spécimen était âgé de 5 ans. La sex-ratio de 1 : 1,35 (n = 935) est en faveur des femelles. En utilisant la méthode de la courbe de capture, le coefficient instantané de mortalité totale Z a été estimé à 1,07 par an. Les coefficients instantanés de mortalité naturelle M et de la pêche F sont de 0,58 et 0,49 par an, respectivement. Le taux actuel d'exploitation (E = 0,46) indique que la population est hautement exploitée, probablement au-dessus d'un niveau soutenable.

Key words. - Cyprinidae - *Vimba vimba persa* - Caspian Sea - Age - Growth - Mortality.

The enclosed Caspian Sea is the world's largest brackish water body, comprising nearly 40% of the Earth's continental surface water (Dumont, 1998) located between latitudes 47.07'N and 36.33N and longitudes 45.43'E and 54.20'E. Its surface level at the moment is about -26.5 m below MSL, its surface area being of 386,400 km^2. The water of the Caspian Sea is slightly saline; if we compare the Caspian water with oceanic water, it contains 3 times less salt (Caspian Sea Biodiversity Database, 2010).

Various commercially important fish species occur in the Caspian Sea. The highly valued *Vimba vimba persa* (Pallas, 1811), locally called "Siah cooli", is landed in the southern Caspian Sea, Iran, with catches of about 100 tonnes per year in the 1980s over the whole Caspian Sea basin (Kuliev, 1988). In the past five years, the maximum catches of *V. vimba persa* in Iranian waters were recorded in 2009-2010 at 474 tonnes (SHILAT (Iranian Fishery Organization), 2010).

V. vimba belongs to the Cyprinidae and inhabits the coastal areas of the Caspian, Black, Baltic, and North Seas (Rabova *et al*., 2003). The males become sexually mature at 2-4 years. This species engages in short-distance anadromous migrations, moving to spawn upstream in barbell or grayling regions (Luszczek-Trojnar *et al*., 2008). *V. vimba*, primarily inhabiting the South and Middle Caspian, is an anadromous fish of small size, entering rivers for spawning and spending the rest of its life at Caspian Sea. The *Vimba* usually breeds in deltaic water bodies, with depths ranges from 0.2 to 1 m (Askerov *et al*., 2001).

Kiabi *et al*. (1999) considered this species to be almost threatened in the South Caspian Sea basin, according to IUCN criteria. Weirs are a problem for this species in Iran as they block the spawning migration, fish massing below the obstruction, and causing re-absorption of eggs and sperm (Holčík and Oláh, 1992).

By the review of the studies carried out on the biology of

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this fish, it was shown that few studies on sex, age, growth and mortality of *V. vimba persa* in Iranian waters of the Caspian Sea have been done (Ghaninezhad *et al*., 1999; Rahmani *et al*., 2000; Arzpeyma *et al*., 2001; Shoormaj *et al*., 2002; Yektan *et al*., 2004). The objective of the present study is to fill the information gaps on the population biology: length and age structure, growth parameters, sex structure, age at first capture and fishing and natural mortality of *V. vimba persa* in Iranian waters of the Caspian Sea.

MATERIALS AND METHODS

Vimba vimba persa were caught by using beach seines, gillnet and cast net at six landing sites of Ramsar, Tonekabon, Chalus, Mahmoud-abad, Farah-abad and Amir-abad (Fig. 1). A total of 994 *V. vimba persa* specimens were sampled in monthly intervals from October 2008 to September 2009. Fork length was measured to the nearest 0.1 cm and total weight to the nearest 0.1 g.

Scales has been used to determine annual age (Robillard and Marsden, 1996), although it is the otolith which is applied over the broadest age range in many species (Secor *et al*., 1995). For scale analysis, 6-10 scales were removed (DeVries and Frie, 1996). Scales of 845 specimens were taken from the middle of the body, behind the pectoral fins and above the lateral line. They were then placed in labelled envelopes and returned to the laboratories for age reading and analysis. The scales were washed and placed in small covered Petri dishes with tap water. Then, the organic layers of scales were removed by rubbing and washing in tap water (Fazli *et al*., 2008; Afraei Bandpei *et al*., 2010b). A number of samples of scales were aged by a second person to verify age estimates. Age composition of catch was derived from the length composition data and age-length keys.

The relation weight-length was calculated applying the exponential regression, following the equation: $W = a \times L^b$, where W = total wet weight (g), L = fork length (cm), a and b = coefficients to be estimated (Ricker, 1975).

Parameters estimation was conducted by least squares linear regression on log-log transformed data:

$$\ln(W) = \ln(a) + b\ln(L).$$

T-test for departure from isometry (b = 3) was carried out using Pauly (1984):

$$t = s.d.(x) / s.d.(y) \times [(b - 3) / \sqrt{1 - r^2}] \times \sqrt{n - 2},$$

where s.d.(x) and s.d.(y) = standard deviations of the natural log L and natural log W values, respectively, and n = sample size.

The von Bertalanffy growth curve was fitted to the observed length at age data for the resulting age-length key using a non-linear estimation method following:

$$L_t = L_\infty (1 - e^{-K(t - t_0)}),$$

where L_t = length at age t, L_∞ = theoretical maximum length, K = growth coefficient and t_0 = hypothetical age for $L_t = 0$. The growth performance index ϕ' was estimated to compare the growth parameters obtained in this paper with those calculated by other authors. This index was calculated by the equation (Pauly and Munro, 1984):

$$\phi' = \log K + 2\log L_\infty.$$

Survival rate (S) was calculated using the catch curve method (Ricker, 1975). To estimate S, age compositions of Caspian vimba were used as input data. The instantaneous coefficient of total mortality (Z) was transformed from the survival rate as $Z = -\ln S$.

The instantaneous coefficient of natural mortality (M) was estimated using the ZM model (Zhang and Megrey, 2006) with von Bertalanffy growth parameters and a maximum age (t_{max}) of 6 for *V. vimba persa* (Arzpeyma *et al*.

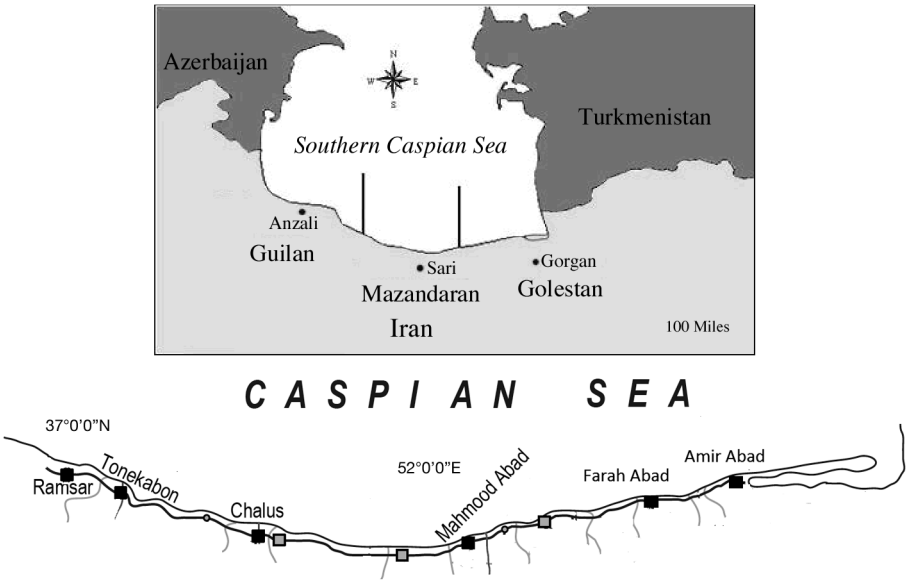

Figure 1. - Geographical location of sampling sites (■) for *Vimba vimba persa* in the Iranian coasts of Caspian Sea.

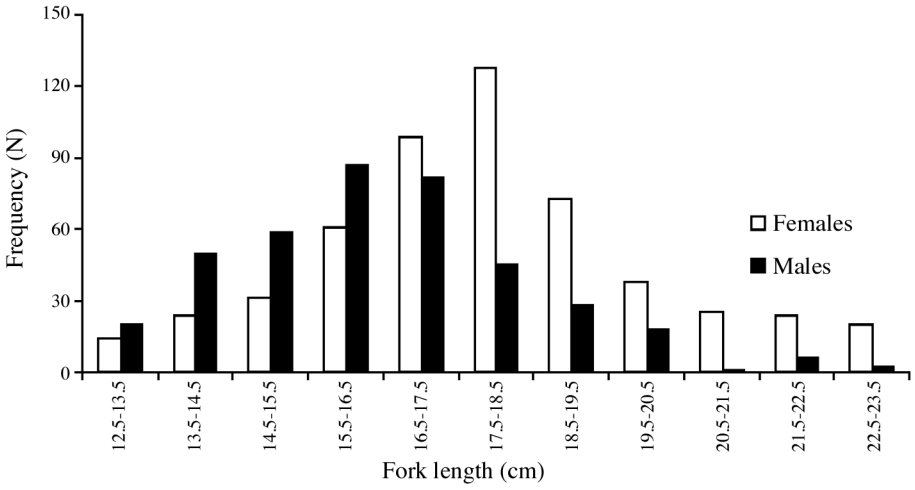

Figure 2. - Fork length distribution of males and females *Vimba vimba persa* during 2008-2009. N = 935

2001; Holčík and Oláh, 1992). The equation of ZM model is:

$$\hat{M} = ßK / e^{K(t_{mb} - t_0)} - 1,$$

where β = power parameter of length-weight relationship, t_0 = hypothetical age for $L_t = 0$, and t_{mb} = critical age, which can be estimated as $t_{mb} = 0.440\ t_{max}$ (Zhang and Megrey, 2006). The instantaneous coefficient of fishing mortality (F) was calculated using: F = Z – M (King, 1996).

In general, age at first capture of a stock is estimated directly from fishing experiments either by attaching a small-meshed cover over the cod-end or from the size composition of the catches of nets of smaller meshes caught at the same time and place (Gulland, 1983). However, the length-converted catch curve method in Pauly (1984), was used in this study. The exploitation ratio (E) was estimated according to the following equation: E = F / Z (King, 1996).

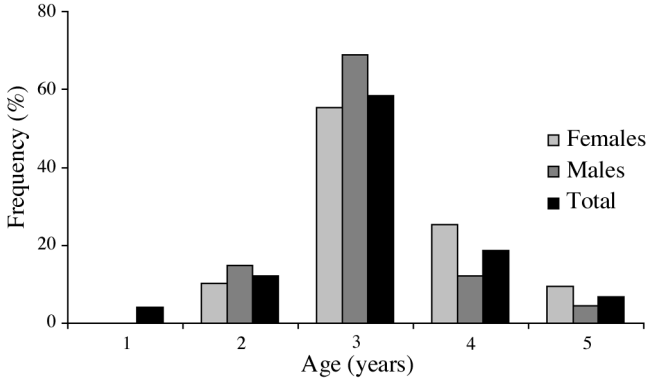

Figure 3. - Age composition of *Vimba vimba persa* in Iranian commercial catches during 2008-2009. N = 845.

RESULTS

The lengths and weights of *V. vimba persa* ranged from 9.5 to 23.4 cm, average length 16.8 cm (± 2.2); and from 11.6-178.3 g, average weight 71.9 g (± 32.2), respectively. Female sizes averaged 17.8 cm (± 2.2) and 82.7 g (± 31.4) while male sizes averaged 16.3 cm (± 2.0) and 65.0 g (± 25.7); females being significantly larger than males ($t = 10.4$, $p < 0.001$ for length; $t = 9.5$, $p < 0.001$ for weight; Tab. I, Fig. 2).

The maximum age in the sample was 5^+ years old, with length 23.4 cm. Figure 3 shows that the 3^+ years age group is the largest, with 55.2% represented in females, 68.7% in males and 58.3% for the whole sample, respectively.

The fork length and weight relationships are: overall, $W = 0.0122L^{3.048}$ ($R^2 = 0.95$, standard error of b = 0.0210 and a = 0.0007; Fig. 4); female, $W = 0.0152L^{2.971}$ ($R^2 = 0.92$, standard error of b = 0.0377 and a = 0.0016); and male, $W = 0.0099L^{3.128}$ ($R^2 = 0.93$, standard error of b = 0.0436

Table I. - Mean fork lengths (cm) and weights (g) of *Vimba vimba persa* in Iranian region of the Caspian Sea

Sex	N	Fork length (cm)		Weight (g)	
		Mean ± SD	Min-Max	Mean ± SD	Min-Max
Female	537	17.8 ± 2.2	12.9-23.4	82.7 ± 31.4	27.0-178.3
Male	398	16.3 ± 2.0	12.5-22.6	65.0 ± 25.7	25.9-163.0
Immature	59	11.4 ± 0.9	9.5-12.5	20.1 ± 4.7	11.6-28.3
Total	994	16.8 ± 2.58	9.5-23.4	71.9 ± 32.2	11.6-178.3

Table II. - Average of fork length and weight of *Vimba vimba persa* in Iranian waters of the Caspian Sea.

	Age group (year)					Total
	1	2	3	4	5	
N	35	102	493	157	58	845
$\overline{FL}$ (cm)	10.7	13.7	16.5	19.30	21.8	
S.D.	0.70	0.61	0.96	0.74	0.75	
$\overline{W}$ (g)	16.9	34.4	64.5	105.1	138.4	

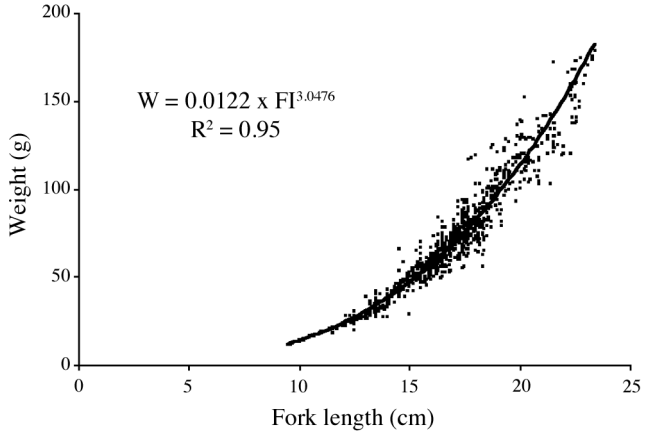

Figure 4. - Relationship between fork length and weight of *Vimba vimba persa*. N = 994.

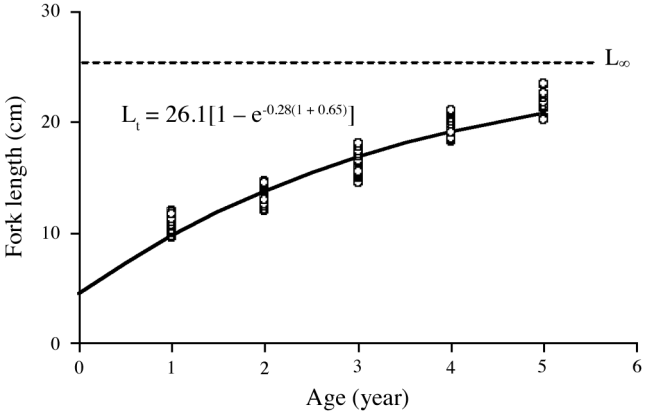

Figure 5. - Theoretical growth curve for the fork length of *Vimba vimba persa* in the Caspian Sea.

and a = 0.0099). The slopes (b values) of the length-weight relationships, 3.048 and 2.971 for the whole sample and for females were not significantly different from 3 ($p > 0.05$) while that for males, 3.128, was significantly higher than 3 (t-test, $t = 3.4$, $p < 0.001$), suggesting isometric growth for females and positive allometric growth for males.

Ages of *V. vimba persa* determined from scale analysis ranged from 1 to 5 years (Tab. II), suggest a rapid growth during the 1st year and a slow increase during the last 4 years (Fig. 5). The von Bertalanffy growth parameters estimated from the age-at-length data are $L_\infty = 26.1$ cm, $K = 0.28$ year^{-1}, and $t_0 = -0.65$ (growth performance index estimated 2.28).

The overall sex ratio (male to female) was 1:1.35 (n = 935), which differed significantly from the expected 1:1 ($\chi^2 = 20.7$, $p < 0.001$; Tab. III). Females were more abundant in January, April, May, June and August ($p < 0.05$) and males predominated in February and March ($p < 0.05$) while no significant difference was found for the other months of the year ($p > 0.05$; Tab. III).

Age at first capture (t_c) of *V. vimba persa* was estimated

Table III. - Chi-square test for *Vimba vimba persa* sex ratio comparisons by month in Iranian waters of the Caspian Sea

P	χ^2	Total	Sex		Month	Year
			Male	Female		
0.052	3.77	52	19	33	Oct	2008
0.115	2.48	58	23	35	Nov	
0.063	3.46	74	29	45	Dec	
0.024	5.12	50	17	33	Jan	2009
0.033	4.55	97	59	38	Feb	
0.028	4.84	129	77	52	Mar	
0.006	7.69	125	47	78	Apr	
0.001	14.56	127	42	85	May	
0.002	9.33	67	21	46	Jun	
0.258	1.28	50	21	29	Jul	
0.009	3.31	51	19	32	Aug	
0.345	0.89	55	24	31	Sep	
0.001	20.66	935	398	537	Total	

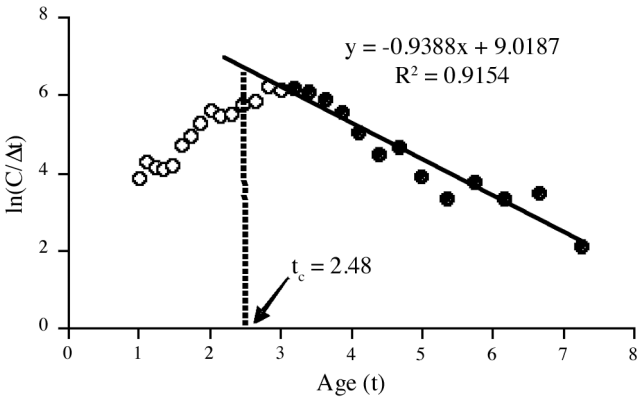

Figure 6. - Estimation of the selection ogive of *Vimba vimba persa* from length-converted catch curve analysis using the Pauly (1984) method. Black dots = used data.

at 2.48 years and the annual survival rate (S) at 0.343 year^{-1} from length converted catch curve (Fig. 6). Given this survival rate, the instantaneous coefficient of total mortality (Z) of *V. vimba persa* was calculated at 1.07 year^{-1}. The instantaneous coefficient of natural mortality obtained from the ZM model was 0.58 year^{-1} and the instantaneous coefficient of fishing was calculated at 0.49 year^{-1}. With the estimates of instantaneous coefficients of total and fishing mortality, the exploitation ratio was computed at 0.46.

DISCUSSION

Holčík and Oláh (1992) and Arzpeyma *et al*. (2001) recorded *V. vimba persa* maximum ages of 6 years in Anzali lagoon (Tab. IV), while the present study shows a maximum

Table IV. - Comparison of sex composition, age range and growth parameters of *Vimba vimba* between previous and present study.

Author	Species	Study area	N	Study time (month)	M:F ratio	Age (min-max)	b	L_∞ (mm)	K (y^{-1})	t_0 (year)	φ'
Abdurakhmanov, 1962	*V. vimba*	Terek River	–	–	–	–	–	331.5	0.178	0.06	2.29
Holčík and Oláh, 1992	*V. vimba*	Anzali lagoon	–	–	–	3-6	–	324.1	0.195	0.04	2.31
Ghaninezhad *et al*., 1999	*V. vimba*	South of Caspian sea	–	–	–	2-5	–	294.0	0.219	-2.29	2.28
Rahmani *et al*., 2000	*V. vimba*	Shiroud River	–	–	–	2-4	–	238.6	0.510	0.30	2.46
	V. vimba	Anzali lagoon	–	–	–	2-4	–	195.5	0.640	0.43	2.39
Arzpeyma *et al*., 2001	*V. vimba persa*	Anzali lagoon	135	3	1:0.63	3-6	2.72	321.0	0.078	-4.35	1.92
Shoormadj *et al*., 2002	*V. vimba persa*	Mahmoud-abad to Amir-abad	166	3	1:5.64	2-5	2.90	228.8	0.475	-0.37	2.40
Froese and Binohlan, 2003	*V. vimba*	Czech Rep, Berounka River	–	–	–	–	–	278.0	0.218	-0.22	2.23
Yektan *et al*., 2004	*V. vimba persa*	Ramsar and Tonekabon	259	5	1:0.99	2-5	2.34	243.8	0.151	-3.09	1.95
Present study	*V. vimba persa*	South of Caspian Sea	994	12	1:1.35	1-5	3.05	261.0	0.280	-0.65	2.28

age of 5 years, i.e., concurrent with those by Ghaninezhad *et al*. (1999); Shoormaj *et al*. (2002); Yektan *et al*. (2004) in South Caspian Sea. In contrast, Rahmani *et al*. (2000) recorded a maximum age of 4 years in the Shiroud River.

The exponent b of length-weight relationships estimated in this study was in accordance with the range of *b* values, usually between 2 and 4, found by Bagenal and Tesch (1978), i.e., falling within the range suggested by Carlander (1977) and confirmed by Froese (2006). The overall b value of 3.048 is close to that reported by Shoormaj *et al*. (2002), but different from that by Arzpeyma *et al*. (2001) and Yektan *et al*. (2004), in the Caspian basin (Tab. IV). The slopes (b values) were significantly different between two sexes. This variation in *b* could attribute to different stages in ontogenetic development such as: differences in age, maturity, sex and species. Environmental conditions (as well as seasonality, stomach fullness, disease and parasite loads) can affect the value of b (Le Cren, 1951; Bagenal and Tesch, 1978).

The overall male:female ratio was 1:1.35, significantly different from 1:1. Similar results were reported by (Shoormadj *et al.,* 2002), but different from those reported by Arzpeyma *et al*. (2001) and Yektan *et al*. (2004) in the Anzali lagoon and Caspian Sea (Tab. IV; 1:0.63 and 1:0.99, respectively). Some references such as Arzpeyma *et al*. (2001); Yektan *et al*. (2004) and Shoormadj *et al*. (2002) related to southern part of the Caspian Sea, which showed us different results, were due to restricted study area, time and sample size.

There are only a few studies on the growth of *V. vimba persa* as shown in table IV. The estimated value of L_∞ was higher than the observed L_{max}, which supported the hypothesis suggested by Taylor (1960) and Mathews and Samuel (1990) that $L_{max} \approx 0.95L_\infty$. L_∞ in the present study is close to those found by Froese and Binohlan (2003), Rahmani *et al*. (2000) in the Shiroud River and Yektan *et al*. (2004) in Ramsar and Tonekabon, but different from others in the Caspian Basin (Tab. IV).

In the present study, the K value of *V. vimba persa* was estimated 0.28/yr. Branstetter (1987) categorized a K value of 0.05-0.10/yr for slow growing species, 0.10-0.20/yr for species with moderate growth, and 0.20-0.50/yr for rapid growing species. Therefore, *V. vimba persa* in the southern Caspian Sea could be considered as a rapid growing fish.

The φ' of *V. vimba persa* was 2.28, closed to those found by Holčík and Oláh (1992), Abdurakhmanov (1962) and Ghaninezhad *et al*. (1999) in the Caspian basin and Froese and Binohlan (2003) in Czech Republic, Berounka River, but different from those reported by Rahmani *et al*. (2000), Arzpeyma *et al*. (2001) and Yektan *et al*. (2004) in the Caspian basin (Tab. IV). Etim *et al*. (1996) reported that growth coefficients and φ' are species-specific parameters and their values are usually similar within related taxa and have narrow normal distributions. However, K and φ' of *V. vimba persa* in the present study were different from those found even in same species along the Caspian basin (Tab. IV). Similar result reported by Afraei Bandpei *et al*. (2010a) for Caspian kutum, *Rutilus frisii kutum* in the southern coast area of the Caspian Sea. They reported these changes could

be due to carnivorous nature and food availability, ecological conditions, geographical changes and genetics variations for the species (Afraei Bandpei *et al*., 2009).

During the last decade, the environment of the Caspian Sea has changed significantly in response to various factors, such as fluctuations of the water level, pollution (Ivanov, 2000; Salmanov, 1999), and introduction of exotic species. In particular, the invasive jellyfish (Ctenophora, *Mnemiopsis leidyi*), that appeared in 1999 (Ivanov *et al*., 2000), affected all components of the ecosystem (Roohi *et al*., 2010), and had specially effects on two pelagic species (anchovy, *Clupeonella engrauliformis* and bigeye kilka, *C. grimmi* (Fazli *et al*., 2007, 2009), and on golden grey mullet and Caspian kutum stocks (Fazli *et al*., 2008). Therefore, the ecological changes caused by *Mnemiopsis leidyi*, also restricted time duration, sampling size and area, can explain these changes in ecological parameters of *Vimba vimba persa* in the Caspian region.

During the years 2008-2009, the exploitation ratio was 0.46. This is slightly lower than the rate of 0.5 suggested by Gulland (1983), as the theoretical exploitation rate that could maximize harvest. In most instances, this theoretical rate has proved to be too high, and not sustainable. Therefore, the current exploitation ratio indicated that the population seems to be highly, and probably not at a sustainable level, exploited.

Acknowledgements. - We express our sincere gratitude to all those who contributed to sample collection and data analysis, especially Dr. Ghasemi, Mr. Koor and Taleshian and Mrs. Yektan.

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Reçu le 19 novembre 2010.
Accepté pour publication le 10 octobre 2011.